BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI
Second Semester 2022-2023
Mid Semester Exam (Open book)
Industrial Instrumentation and Control (INSTR F343)

Time*:90 Minutes* ***Max Marks:*** *60* ***Date:****15.03.2023*

Note*: This question paper has 4 questions. Assume and clearly specify any missing data suitably. Marks are indicated against each question. Unless otherwise specified, assume final control element and measurement element transfer functions as unity.*

Question 1: A system's transfer function is estimated as $\widetilde{G_P}(s)$, and is given below. Design an IMC based feedback controller for this system and find the proportional gain (K_P), integral gain (K_I), and derivative gain (K_D). Assume, filter transfer function $f(s) = 1/(3s+1)$. [12]

$$\tilde{G}_P(s) = \frac{4(1-2s)}{(20s+1)(5s+1)}$$

Question 2: A feedback control system's block diagram is shown in Fig. 1, where **R(s)** is reference signal, **Y(s)** is process output and **D(s)** is disturbance, all in deviation variable form. A control engineer wants to design the controller $G_C(s)$ to obtain a perfect regulatory action in steady state. One of the following closed loop responses, $G_{CL}(s) = Y(s)/D(s)$, may be chosen,

(A) $G_{CL}(s) = 1/(\lambda s+1)$ **(B)** $G_{CL}(s) = (\gamma s+1)/(\lambda s+1)$ **(C)** $G_{CL}(s) = (\gamma s)/(\lambda s+1)$

(i) To achieve the desired control objective, as indicated above, choose the most appropriate closed loop response from the indicated options (A, B, or C) and clearly write the reason for the same.
(ii) Obtain a controller $G_C(s)$ for the chosen $G_{CL}(s)$ in part (i). Assume, process transfer function $G_P(s) = K_P/(1+sT)$ and disturbance transfer function as, $G_D(s) = K_P/(1+sT)$. Indicate the controller in a standard parallel PID form. [18]

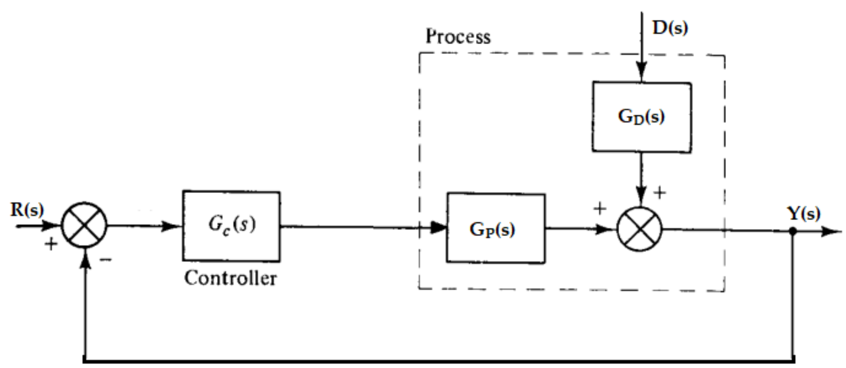

Fig. 1

Question 3: Consider a constant volume CSTR in which pure material 'A' enters at a volumetric flow rate of 25 dm^3/s and at a concentration of 0.2 mol/dm^3. Given: $(-r_A) = kC_A^2$ and the dynamic equation describing the behavior of CSTR is,

$$V\frac{dC_A}{dt} = F_i(C_{Ai} - C_A) - V(-r_A)$$

(a) At steady state, what CSTR volume is necessary to achieve a 90% conversion when k = 10 dm^3/(mol-s)?
(b) What is the time constant of the CSTR? [15]

Question 4: Assume a tank level system has linear dynamics with a static gain of 0.08 m/LPM (LPM – liters per minute) and time constant as 10 minutes. The range of output, i.e., height of the tank is between 0 – 2 m and the input flow rate range is 0-500 LPM obtained using an electronic control valve. The valve input is in the range of 0 – 5V which is converted in the flow rate range of 0-500 LPM. A level sensor has also been used which converts the level of 0–2 m to 0 – 5V. Assume level sensor and control valve are linear in nature and both have zero order dynamics.
(i) Draw the block diagram of process control loop with transfer function with numerical values inside each block and input output variable of each block with proper units **(ii)** Find the value of gain of proportional controller such that the closed loop response has a time constant of 5 minutes. **(iii)** Design an electronic proportional controller with value of the gain found in part (ii), assume controller output at steady state P(0) = 50%. [15]

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